Some Thoughts about the Interindustry Macroeconomic Model

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1 Background

The world economy continues to become more globalized, more technologically advanced, and more sensitive to changes in the global financial system. Huge changes are occurring under our feet as the world 'rebalances' from the global financial crisis. Outlines of the 21st century economy are already apparent, with China verging on becoming the world's largest economy, and many countries in Southeast Asia continuing to rise faster than the world average. Mature economies such as the U.S. and several European countries have slowed, due partly to slowing labor force growth and aging populations, as well as lower rates of productivity growth. Most of the lesser developed economies (LDCs) are still struggling, but trying to develop human capital and attract foreign investment to become an integral and productive part of the 21st century world economy.

How can we best understand the dynamics driving the differential rates of economic growth, competitiveness and trade? The macroeconomic modeling approach is certainly useful, as it can tell a powerful story with a minimum of data. However, to understand many of the key questions confronting the different world economies, such as productivity, growth, investment and trade, industry analysis is important, and interindustry modeling has much to offer. This approach not only illustrates linkages from the demand side, but also can capture the cascading effects of relative price changes.

Linkages between countries are extremely important, and the nexus of trade and finance has become more intertwined and complex in recent years. Sectoral models can be linked through bilateral trade flows, and grasping the changing patterns of these flows of merchandise and services trade can help understand how one country's growth can stimulate that of other countries, or how recession in a large country such as the U.S. can spread to Europe and beyond.

For several years, the Inforum group has focused on the development of national level models that seek to combine the best features of the macroeconomic and interindustry modeling. In this paper, I will focus on some particular aspects of the Inforum approach to interindustry macroeconomic (IM) modeling. I will to try to present them in a way that makes it easy to compare and contrast this approach with others that serve similar goals. After some brief historical notes in section 2, the structure of a typical model is described in section 3. Section 4 touches on a recent study of defense cuts, providing context for the behavior of dynamic multipliers. The next two sections (5 and 6) review some typical methods developed by Inforum for modeling personal consumption and investment expenditures. Section 7 provides a brief review of the Inforum software which is used by the U.S. group as well as international partners and others to build models. The interesting, and relatively unexplored topic of "soft constraints" is discussed in section 8. Section 9 describes the Inforum Bilateral Trade Model (BTM) and its future outlook, and the last section summarizes and muses about what's ahead.

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2 History

Wassily Leontief clearly realized the dream of Quesnay, Walras and other predecessors of formulating a pragmatic, empirically based accounting system that enabled the joint determination of production and prices in an interrelated, consistent way. He was quite eager to use his new system as a tool to explore important economic questions such as the effects of productivity on prices, the effects of technical change on prices and economic structure, the impacts of exports and imports on employment, and the interactions between factor payments such as wages and capital income with prices.[2]

At nearly the same time that Leontief was developing the first input-output tables for the U.S., Jan Tinbergen was pioneering the creation of econometrically estimated structural models, which was soon followed by the work of Lawrence Klein and Arthur Goldberger.[3] Taking advantage of the recently developed current and constant price National Income and Product Accounts for the U.S., these models represented the economy as a set of interdependent, aggregate equations.

Clopper Almon was a student of Leontief at Harvard, and contributed a consistent method for forecasting investment, as well as an operational input-output forecasting model for the U.S., written in Fortran. When Clopper came to the University of Maryland in 1966, work on the model continued, and the Maryland Interindustry Forecasting Project (MIFP) was started soon afterwards, later changing its name to Inforum (Interindustry Forecasting at the University of Maryland). Clopper also taught a course in building macro models, using software that was developed for the course, but which was of course useful for the Inforum model as well. Early versions of the model focused on the final demand equations and input-output solution, and included the first application of the product-to-product technology algorithm[4], as well as logistic equations for forecasting coefficient change. In later versions, a "price-income" side model was developed, that included econometric equations for value added by industry and the input-output price calculation. In the early 1980s, the two parts of the model were integrated, and a significant amount of additional macroeconomic equations were added in what was called "the Accountant". In the U.S., this heralded the birth of the Inforum *LIFT* model, which incorporated the work of several Inforum PhD theses.[5] The *LIFT* model has continued to evolve through several versions. The latest versions are built using software developed by Clopper and other Inforum staff.[6]

Early on, Inforum reached out to researchers from other countries at International Input-Output Conferences as well as from a stint working at IIASA in the late 70s. Inforum offered a partnership arrangement where software, techniques and assistance were given in model development, in exchange for sharing the resulting model that was developed. Some of the first Inforum models outside of the U.S. were for Austria and Italy. Following soon after were models for France, Japan and South Korea. Soon after the IIOA conference in Seville in 1993, Inforum began hosting its own World Conferences, the first being held in Rennes, France, and the most recent in Listvyanka, Russia, on the shore of Lake Baikal. The next conference will be held in Alexandria, Virginia, in the first week of September 2014. Many Inforum models are now linked

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[2] Leontief (1951), a classic in 20th century economics, contains several chapters describing his experiments exploring these questions.

[3] Tinbergen (1939), Klein and Goldberger (1964).

[4] Almon (2000).

[5] Monaco (1984), Meade (1990), Ma (1995), Janoska (1996), Dowd (1999), Wilson (2001) and Li (2006).

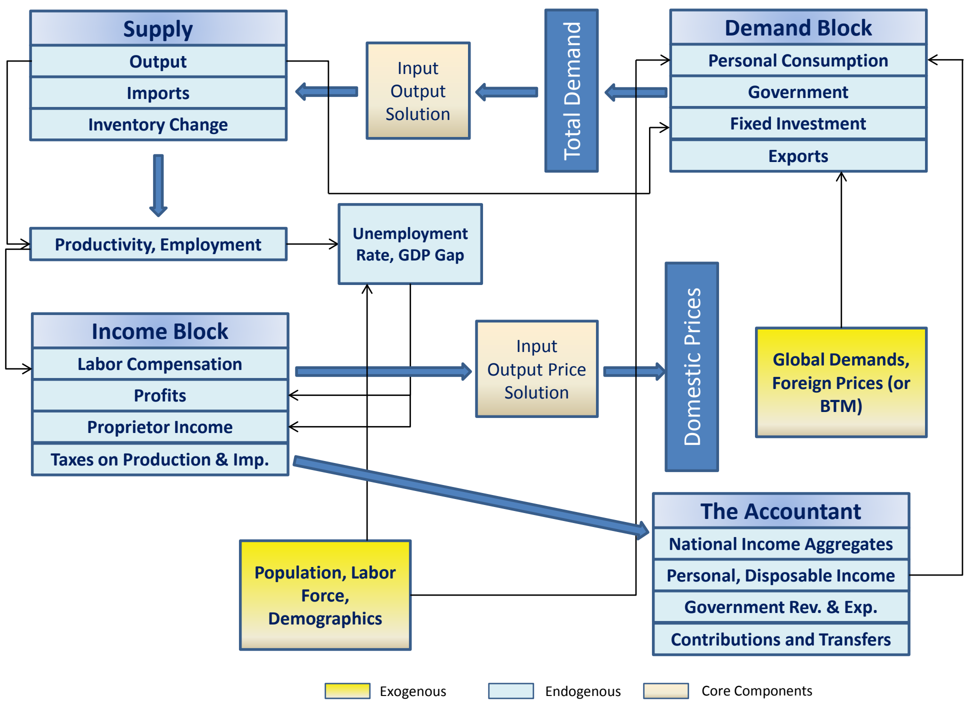
[6] The *G7* and *Interdyme* software are described in section 6.

as part of a bilateral trade model which includes 13 country models.[7] Several other models, including one for Russia, will soon be added to the system.

3 General Structure of an Interindustry Macroeconomic Model

Inforum models can be characterized generally as IO Econometric models[8]. The core of the model consists of the multisectoral quantity and price relationships. Detailed variables are aggregated to obtain the aggregate macroeconomic product and income versions of GDP. Figure 1 below shows a simple schematic diagram of a typical model.

Figure 1. Summary Diagram of Representative Model



Macroeconomic properties of the models are very important, but it may be more realistic and useful to model behavior at the industry level. For example, investments are made in individual firms in response to market conditions in the industries in which those firms produce and compete. Aggregate investment is simply the sum of these industry investment purchases. Decisions to hire and fire workers are made jointly with investment decisions with a view to the outlook for product demand in each industry. The net result of these hiring and firing decisions across all industries determines total employment, and hence the unemployment rate. In the real world economy pricing decisions are made at the detailed product level. Modeling price changes

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[7] An early version of the linked system was presented at this conference by Almon (1984). Nyhus (1991) describes the previous system in more detail. Ma (1995) describes the development of the Bilateral Trade Model and the equations used in the linking. Bardazzi and Ghezzi (2014) describe current work on the system, in a paper presented at this conference.

[8] Almon (1991) is a good introduction to the general idea behind the IM model. See West (1995) for a comparison of IO Econometric and CGE models. Grassini (2001) provides a more lengthy description of the typical Inforum model.

at the commodity level certainly captures the price structure of the economy better than an aggregate price equation. In an, prices and incomes are forced into consistency through the fundamental input-output identity, and the aggregate price level is determined as current price GDP divided by constant price GDP.

Econometric equations are estimated for exports, imports and inventory change by commodity, personal consumption by category, and equipment and structures investment by industry. Consumption and investment bridge matrices are used to translate the consumption by category and investment by industry to the commodity level. Exports, government, consumption and investment are calculated in the Demand Block before doing the IO solution. The Gauss-Seidel solution used to solve the quantity IO system jointly determines domestic output, imports and inventory change. Input-output coefficients are projected to change over time, using a logistic curve.

Employment and hours worked are typically estimated as productivity functions, linking hours to industry output, and average hours worked equations, linking employment to hours. In the Income Block, wage equations by industry are used to obtain labor compensation. Other components of value added, such as profits, depreciation and proprietors' income, may also be estimated, depending on the data availability in any given country. Some countries have only compensation, gross operating surplus, and indirect taxes comprising total value added.

Value added is used in the IO price solution to obtain prices by commodity or by industry, depending on the type of IO table available.[9] Some prices may be set exogenously, in which case several value added components need to be revised to maintain consistency. Alternatively, the modeling approach can focus on estimating price regressions directly, and then adjusting value added to be consistent with price[10]. There is no need anywhere in the model to deflate value added, and there is no logical need to have a constant price IO table that adds up down the column.[11] The income side of the model is calculated in nominal terms only, though several variables may be deflated by the GDP deflator or average consumption deflator to obtain the "real" versions of those variables.

The macro accounts include most of the tables used in a typical SNA presentation, or in the case of the U.S., the National Income and Product Accounts (NIPA). A typical model will also include population by demographic category, labor force and participation rates, financial variables including monetary aggregates and interest rates, and full detail on transfers, contributions and taxes in the government accounts. Government expenditures by detailed category are usually specified exogenously in real terms and converted to nominal values using a price.

Prices calculated in the price-income side of the model are used as variables in the personal consumption, equipment and structures investment and export/import equations. The result of the expenditure side calculation implies a certain level of GDP and of total employment (and unemployment rate), as well as sectoral outputs. These variables may all play a role in the wages

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[9] The U.S. LIFT model and several other models use a "purified" commodity-by-commodity table using commodity technology, using the "PTP" technique outlined in Almon (2000). Some models use industry-by-industry tables.

[10] This is the approach followed by the German Inforum team, GWS, in their *Inforge* model. See Lutz, et. al. (2003).

[11] See Meade (2007) and Almon (2009) for suggestions about possible problems that arise from using double-deflated value added.

and profits (or surplus) equations, so that tightness or slack in the economy affects the growth of value added and hence prices.

The typical model solves annually, and a typical forecast interval is from 10 to 50 years, although some of the models have been developed for very long-term applications. The models are dynamic, in that many of the equations include lagged effects or relations using first differences. Although the models are "bottom-up" in that detailed data is used to form the macro-aggregates, they may be controlled from the top down if necessary, to force consistency with a macro model forecast.[12]

4 Multipliers and Induced Effects

A common application of the model is to estimate effects on industry output and jobs from an exogenous shock. Such a shock may be a sudden reduction in spending for defense, as analyzed in Werling (2012). The response of a typical model to an expenditure or price shock can be characterized as disequilibrium in the short-run, but equilibrium in the long-run, tending to return to a potential growth path if moved above or below that path. The derivation of multipliers, such as a total employment multiplier in response to defense spending changes, needs a time dimension. The total size of the multiplier is due partly to the effect of direct and indirect effects from the calculated response of the IO solution in response to the change in defense spending. After a lag, there will also be investment effects, which then change the IO solution, as they are also part of final demand. Additional effects arise through changes in real disposable income which affect personal consumption, resulting in additional changes in final demand. These investment and personal consumption effects are similar to what are termed induced effects in static IO analysis. The total jobs impacts will be blunted somewhat through leakages due to imports.

The defense cut study analyzed the macroeconomic and industry impacts of federal spending cuts established by the Budget Control Act (BCA) of 2011 in addition to further cuts required by sequestration.[13] The time frame of the analysis was from 2012 to 2022. In Figure 2, the CBO Outlook for baseline defense spending (blue) is compared with the lower spending trajectory resulting from BCA and Sequester.

Figure 3 shows the total job losses from the base (red), and decomposes the change in jobs into three components:

1. Direct job cuts within the department of defense, as well as job losses from direct and indirect defense spending effects (blue line, marked with squares). These are the job losses that would be calculated using static IO analysis.
2. Job changes from the changing pattern of investment expenditures, combined with the jobs changes from #1 (green dashed line). The initial drops in investment cause additional job losses, as firms producing investment goods to defense suppliers must reduce their production. These are part of the induced effects.
3. Job changes including all induced effects, arising from interactions between income and personal consumption, as well as changes in prices, government transfers, and other

[12] Such an exercise often reveals potential inconsistencies in the macro model, which is not required to maintain the detailed accounting consistency of an interindustry macro model.

[13] Sequestration is a set of across-the-board cuts that the U.S. Congress decided to impose if there were no credible bi-partisan deficit reduction plan implemented.

stabilizers (red line, marked with '+'s). By 2020, the employment in the defense cut case has just about returned to employment in the base, as the economy has substituted other forms of GDP for defense spending.

Figure 2. Reductions in U.S. Defense Spending from BCA and Sequester

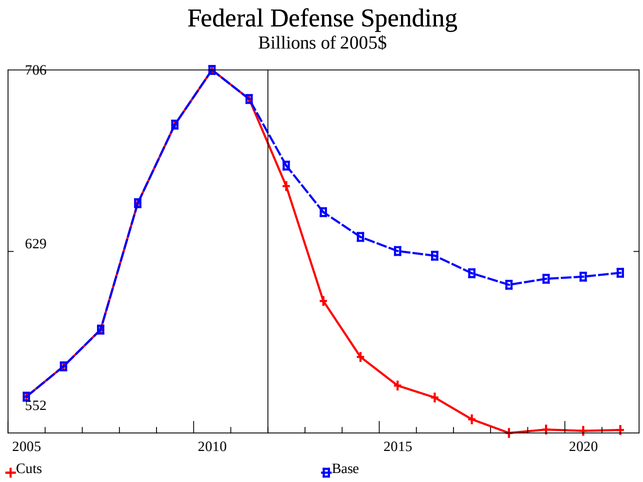
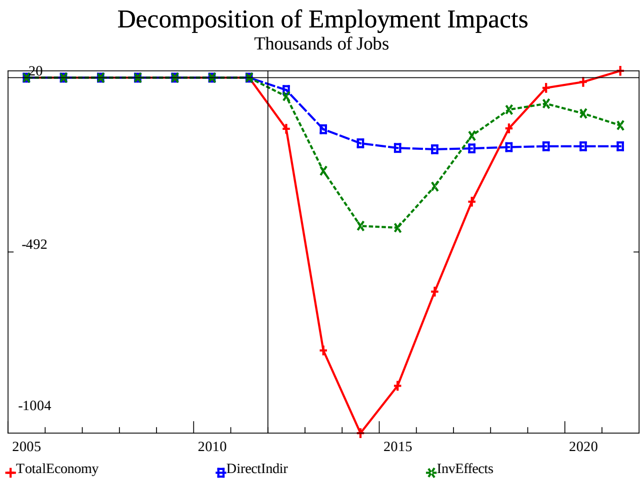


Figure 3. Employment Impacts of a Reduction in U.S. Defense Spending



In these scenarios, GDP and employment begin to return to the baseline levels after 2014. This recovery pattern is a typical response to aggregate demand shocks. The model response to spending increases mirrors that of spending cuts. For a few years the spending increases can increase GDP and jobs, but the economy is constrained by labor force availability and industry capacity. Interest rates and prices will increase, cutting back growth in some sectors.

5 The Perhaps Adequate Demand System (PADS) of Consumption Equations

Personal consumption is the largest single component of GDP, and the pattern of consumer spending between the different categories of goods and services plays a large role in shaping the overall patterns of demand for domestic production and imports. The choice of a functional form and estimation technique for the consumption equations is crucial. The form must be able to accommodate significant growth in real income, such as what is likely to be realized in a long-term forecast. It must also be able to incorporate the effects of demographic and other trends, and changes in relative prices. Both complementarity and substitution should be possible among different goods.

The perhaps adequate demand system (PADS) borrows something of its name from the almost ideal demand system (AIDS), a well-known and often used system of consumption. However, PADS aims to prevent a known failing of AIDS, which is that increasing real income must ultimately drive the consumption of some goods negative, unless it has no effect at all on the budget shares. PADS was derived from an earlier form introduced by Almon (1979), with a multiplicative relation between the income terms and price terms:

$$x_i(t) = \left(a_i(t) + b_i(y/P) \right) \prod_{k=1}^{n} p_k^{c_{ik}}$$

The left hand side of this equation is per capita consumption of product *i* in period t and $a_i(t)$ is a function of time. The *y* in this equation is nominal income per capita; p_k is the price index of product *k* and *P* is the aggregate consumption price index, defined by:

$$P = \prod_{k=1}^{n} p_k^{s_k}$$

where s_k is the budget share of product *k* in the base period of prices. The c_{ik} are constants to be estimated, and are related to the own and cross-price elasticities. One problem with this formulation is the large number of c_{ik} to be estimated. This number can be reduced by assuming symmetry holds in the base period. The number of parameters in can be reduced significantly by partitioning the consumption goods into groups and sub-groups. This approach was taken with the earlier form and is also true of PADS. This method provides a convenient framework for organizing such a large number of consumption goods. Examples of groups are food, transportation, and household furnishing and operation. An example of a subgroup would be proteins, which may include meat, fish and dairy products. The system provides the flexibility of allowing some goods to remain outside of any group.

PADS can be estimated directly with time series data, in which case Y is simply total expenditures. Alternatively, a two-stage approach can be taken, where cross-sectional equations are used to estimate an Engel curve, adult-equivalency weights, and effects of various demographic characteristics for each good, and then the left hand side prediction from this equation can be used as the “income” term in the time series equation.

This two-stage approach is taken for the U.S. *LIFT* model. The cross-section equations in the take the following form:

$$C_i^* = \left(a + \sum_{k=1}^{K} b_k Y_k + \sum_{l=1}^{L} d_l D_l \right) \left(\sum_{g=1}^{G} w_g n_g \right)$$

where:

$C_i^* =$ household consumption expenditures on good *i*

$Y_k =$ the amount of per-capita income (expenditures) within income category *k*

$D_l =$ dummy variable used to show membership in the *j*th demographic group

$n_g =$ number of household members in age category *g*

$w_g =$ adult equivalency weights

$K =$ the number of income groups

$L =$ the number of demographic categories

$G =$ the number of age groups

The demographic categories *D* include region of residence, family size, working status of spouse, college education, and age of household head, all estimated using dummy variables. The two terms in the first factor of the equation are the "piecewise linear Engel curve" and the demographic term. The second factor of this equation is the age-weighted population.

The PADS equations take the form:

$$x_i(t) = \left(a_i(t) + b_i \left(C_c^* / P \right) + c_i \Delta \left(C_c^* / P \right) \right) \left(\frac{p_i}{P} \right)^{\lambda_i} \prod_{k=1}^{n} \left(\frac{p_i}{p_k} \right)^{-\lambda_k s_k} \left(\frac{p_i}{p_G} \right)^{-\mu_G} \left(\frac{p_i}{p_g} \right)^{-\nu_G}$$

where:

$C_c^* =$ cross-section expenditures for corresponding cross-section category *c*

$P =$ overall consumption price index

$p_i =$ the price of good *i*

$p_G =$ the average price index of group *G*

$p_g =$ the average price of subgroup *g*

$\lambda_i =$ individual good *i* price response parameter

$\mu_G =$ the group price response parameter

$\nu_g =$ the subgroup price response parameter

Each consumption good has its own-price elasticity parameter λ_i, plus one μ_G for each group, plus one parameter ν_g for each subgroup. In practice, there are some goods which show so little price sensitivity that they cannot be fit well with this form, and can be estimated outside the system.

The PADS equations are currently estimated for 83 consumption categories for the U.S. *LIFT* model More detail on the equations and the estimation program in Almon (1998). PADS has been used to estimate full consumption systems in Inforum models of several countries, including Italy, Spain, France, Japan and Thailand. The estimation program is available at no charge from Inforum on request.

6 Investment Equations and Flexible Functional Forms

Equipment investment is also an important component of GDP, playing a major role in the medium-term cyclical behavior of the economy, as well as contributing to capacity for further long-term growth. The *LIFT* model forecasts purchases of equipment investment for 61 industries comprising the private U.S. economy. Sales of investment goods at the 110 commodity level are then determined by passing equipment investment by buyer through the investment bridge matrix. Thus the model is capable of determining not only the direct and indirect impacts of a given increase in demand for some good, but also the investment purchases stimulated by that demand, and the capital goods inputs need to produce those investments.

The investment equations are estimated in a two-stage, three equation framework. Factor demands for equipment capital, labor and energy are estimated simultaneously. In the first stage, optimal capital-output, labor-output and energy-output ratios are estimated. In the second stage, the parameters from the first stage are treated as fixed, and equations for net investment, labor and energy are estimated. In this stage, investment is based upon a distributed lag on past changes in output, whereas labor and energy demand are based upon a distributed lag of levels of output.

The first stage equation that is estimated for the optimal capital-output ratio is obtained by using Shephard's Lemma with a generalized Leontief cost function with equipment, labor and energy to obtain:

$$\left(\frac{K}{Q}\right)_t^* = e^{-a_K t}\left[\sum_{j=K,L,E} b_{Kj}\left(\frac{p_j}{p_K}\right)^{\frac{1}{2}}\right]$$

where:

K = capital stock

Q = output

$\left(\frac{K}{Q}\right)_t^*$ = the optimal capital-output ratio

p_j = price of factor j, where $j = K, L, E$

t = time trend

This equation is used in a three equation system to fit the historical capital-output, labor-output and energy-output ratios.

The equation for net investment is derived from the first difference of the optimal capital stock equation and can be expressed by:

$$N_t = e^{-a_{K1} t_1} \left[\sum_{j=K,L,E} b_{Kj} \left(\frac{p_j}{p_K} \right)^{\frac{1}{2}} \right] \sum_{j=0}^{3} w_j^K \Delta Q_{t-j}$$

where:

N_t = net investment

ΔQ = the change in output

The price of capital p_K is the commonly used neoclassical measure:

where:

p_{eq} = the equipment price deflator for this purchasing industry
r = the real AAA bond rate
dep = the average depreciation rate for this industry
T = the effective corporate tax rate
z = the present value of depreciation of one dollar worth of investment
c = the investment tax credit

Constraints are imposed within the estimation procedure to prevent positive own-price elasticities for each factor. The constraint is indeed binding in some industries, resulting in own-price elasticities of zero. The system allows for the modeling of the effects of investment tax policy through the capital cost variable, as well as modeling the effects of different wage rates or energy prices. Note that there is no form of optimization used in this investment function, nor does it use any notion of foresight. We have experimented with versions that used forecasted versions of output and prices, as opposed to their actual values, but the estimation results were not significantly different. However, the equations are based on 3-factor cost functions for each industry using the Generalized Leontief (or Diewert) functional form.

7 G7 and *Interdyme* Software

G7 is a program designed for building models, estimating regressions, developing databanks of scalar, vector and matrix variables, and comparing scenarios and/or counterfactual historical simulations using plots and tables. *Interdyme* is a set of C++ classes designed for the building of interindustry macroeconomic models. *G7* is available for free from the Inforum web site.[14] *Interdyme* is available to Inforum partners and their associates, but may also be obtained on request.

The use of *G7* for developing macro models is described in *The Craft of Economic Modeling*, part 1, which is used in a course for teaching macro modeling at the University of Maryland. Part 2

[14] http://www.inforum.umd.edu/software/g7.html . Extensive documentation is also available there, which is viewable as either html, pdf or windows help files.

describes a fully operational model known as *QUEST*. Part 3 describes the use of *G7* and *Interdyme* to develop Interindustry macro and other multisectoral models.[15]

The historical databanks that are developed in preparation for building a model, and improved and extended as the model development progresses, consist of macrovariables (scalar variables), vectors and matrices. As the model forecasts, the same databanks are extended into the future with the forecast results. This makes it quite convenient to view historical data and forecast in context. Many databanks or scenarios can be loaded into *G7* at any given time, making it possible to compare or plot different outcomes for a given variable. Vector and matrix variables can also be viewed in a spreadsheet format.

A companion program called *Build* or *IdBuild* writes C++ code implementing identities or regression equations, for a macro model, or interindustry macro model, respectively. Regressions and identities for scalar variables can be written by *G7* to files that are processed and translated by *IdBuild* to provide part of the structure of the model. The other main part of the model starts with a template that includes some code for a very simple model. This code is replaced and expanded by the model builder as the model is developed.

Exogenous variables can either be loaded directly in the databank before the model is run, or they can be set through "fixes". Fixes can also be used to modify endogenous variables. They may be specified as overrides, either in level, growth rate or index form. They may be specified as modifiers (add factors or multiples) of endogenous equations or previous fixes. Finally, the model user has the capability to specify various relationships using a family of fix types called equation fixes. *G7*/*Interdyme* is the system that has been used to develop most of the Inforum models, as well as the Bilateral Trade Model, discussed in section 9.

IO coefficients need not be constant, but can be made to change over time either through fixes or endogenous equations. In some of the models, estimation of price responsiveness of some of the coefficients has been successful. Fixes could be used to model, for example, different paths of energy efficiency improvement by sector.

The Interdyme software includes C++ classes for matrix, vector and scalar time series variables that greatly ease the coding of the model, though some C++ programming is still required. Tables can be made of scalar, vector or matrix variables using a program called *Compare*. All results from the model can also be viewed in *G7*, which also eases the comparison of several simulations or scenarios. *G7* is also commonly used to prepare assumptions for exogenous and endogenous variables for the models. Interdyme is made available with support to Inforum International Partners. It can also be made available on request to interested users.

8 Soft Constraints

In a structural model, it is important to incorporate regression equations that have reasonable signs and magnitudes for the regression parameters. This can be achieved with the *G7* "con" command, which imposes a soft constraint. A related technique is the Almon lag, which imposes a soft constraint that distributed lag weights lie along a line or a polynomial of a specified degree. This is achieved using the *G7* "sma" command.

A soft constraint imposes a subjective judgment about the appropriate weights to give to adherence to the constraint versus goodness of fit. This is related to the idea of Theil's "mixed

[15] All three parts are available at http://www.inforum.umd.edu/papers/TheCraft.html.

estimation", and of some Bayesian methods. Mechanically, the soft constraint is programmed by adding a specified number of "artificial observations" to the regression. For example, if one were estimating a consumer demand equation for food using the regression equation:

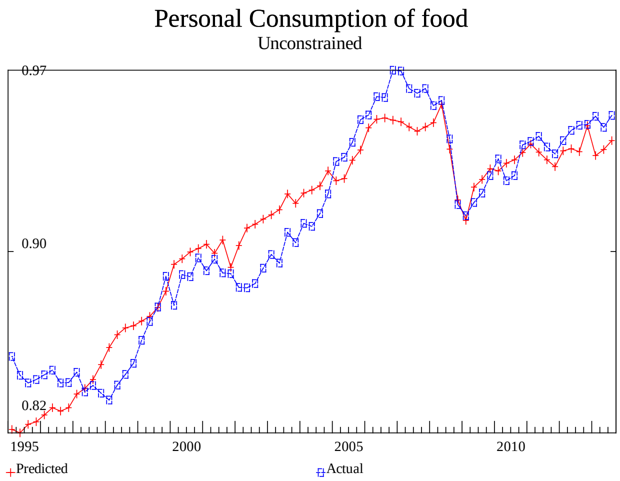
$$\ln cfood \quad = \beta_0 + \beta_1 \ln pfood + \beta_2 \ln Y$$

where

cfood is real per-capita consumption of food
pfood is the relative price of food to the aggregate consumption deflator
Y is real income per capita

Estimation of this equation on U.S. quarterly data from 1995 to 2013 yields the following equation and plot:

$$\ln cfood \quad = -.94 - .55 \ln pfood + .52 \ln Y \ , \quad R^2 = .906$$



One may impose a constraint on this equation to specify the income elasticity β_2 to be equal (or closer) to 0.8. This value may have been taken from another study, or from a cross-sectional regression. The format of this constraint command is

```
con <numobs> 0.8 = a3
```

The regression parameters are identified in *G7* as a1, a2, a3, etc. (a1 is usually the constant term). The 0.8 is the value of the desired constraint. The parameter <numobs> requires some explanation. It specifies how many artificial observations to add to the equation, each of the form

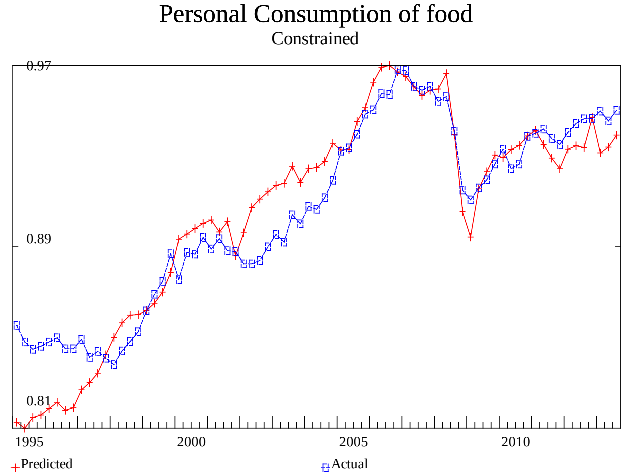
Y	const	X1	X2
0.8	0	0	1

The "error" in this equation is squared and added to the overall sum of squares to be minimized. It represents the distance from the constraint being satisfied. The value of <numobs> one chooses will depend on his subjective preference for the closeness of fit and behavior of other parts of the regression in comparison to the preference for the satisfaction of the constraint. It will also depend on the units of the variables. If the mean of Y and the standard error are large numbers, the value for <numobs> may need to be very large. If they are small, you may need to use a fractional value for <numobs>. In this case, it is easier to think of it as a weighting factor for the constraint. After some experimentation, I use the following:

```
con .005 .8 = a3
```

with the following equation and plot:

$$\ln cfood \;\; = -1.52 - 1.03 \ln pfood + .68 \ln Y \,, \quad R^2 = .852$$



The constraint enabled the equation to move closer to the desired value for the income elasticity, with a relatively small loss of fit. However, the price elasticity increased in absolute value, to be slightly greater than 1.0. Getting the income elasticity up any higher may lead to an unacceptably high price elasticity. Constraining both parameters to desired values may lead to a poorly fitting equation.

In summary, the soft constraint can be a valuable tool in situations where we have information not contained in the time series data. This may either be results from other related studies or literature, or knowledge implied by economic theory. Such knowledge may also stem from experience in working with models, such as what type of equation will contribute to a reasonable model response to changes in policy parameters or exogenous shocks. Applied economists and econometricians alike may feel hesitant to use the soft constraint, arguing that it is too subjective. However, the modeler must make many subjective decisions on the choice of model type, the structure of the model, and the variables and functional forms to use in particular equations. There is much subjectivity involved in this process as well. We think it is best to accept the fact that many choices are subjective, but to make the choices known, so they can be discussed and critiqued. In many types of models, such as CGE and DSGE, model parameters are chosen with regard to calibration on perhaps only one year of data. The soft constraint allows for a combination of fitting historical data and adherence to preconceived parameters, and so is a bit of a hybrid approach, between CGE and strict regression without constraints.

9 Linking of Models Through Bilateral Trade

The Inforum system of macroeconometric, dynamic, input-output models has been producing annual forecasts and analyses of public policy since 1979. The current system contains models for the United States, Canada, Mexico, Japan, Korea, China, Germany, France, United Kingdom, Italy, Spain, Austria, and Belgium. Models of Poland, Hungary, Russia, South Africa, and Thailand have also been developed, but are not yet a part of the linked system.

Each of the country models is linked to the others bilaterally, by commodity, through trade flows and prices. The links are at both the macroeconomic and sectoral level. The macroeconomic side provides the exchange rate assumptions. All other links are at the sectoral level. Thus, steel imports in the USA influence steel exports of Japan; German auto prices affect the price of auto imports to the USA; and, USA grain prices affect Canadian exports of Grain. Exchange rates are exogenous. The system emphasizes the flows of goods and services at the industry level between countries together with the price impacts of such flows.

The models are linked together with the Bilateral Trade Model (BTM). BTM, as its name implies, shows bilateral trade flows between the countries in the system for some 120 commodities. Historical data were based on Statistics Canada's World Trade Database, but work on a new BTM is progressing, based on a combination of UN Comtrade data and EU COMEXT data.[16]

BTM uses country and sector specific data on prices and investment to estimate the import shares and then the importing country's imports to obtain the level of imports from each exporting country. Summing across the importers then yields the exports by country and commodity. These estimates are then used in the country models as indicators of exports. In addition, BTM gives the importing country information on its import prices by commodity.

The following table briefly summarizes the overall capabilities of the individual models. Documentation varies substantially between models. Two were constructed as a part of a Ph.D. thesis; some have substantial papers written concerning their properties; others have only limited documentation. All documentation can be made available upon request.

The forecast horizon of the system is currently 2035. The system can be used to study the industrial and aggregate impacts of macroeconomic developments such as changes in exchange rates, trade policy, and government policy. A recent study, for example, examined the impact on U.S. industries of a U.S. carbon tax with varying degrees of policy response in China.[17]

10 Summary, and What Lies Ahead?

The growing popularity of multisectoral models is due partly to the recognition that for many policy and other economic questions, industries matter. Whether it be the determination of winners and losers from a free trade scenario, comprehensive tax reform, carbon mitigation, impacts of foreign direct investment, health care reform, or rebalancing of the world economy, industry impacts are important for determining changes in employment and income. The integration and consistency achieved by using the IO framework for the computation of outputs and prices provides a further boon. It helps, for example, to determine to what extent different industries prices are affected by a carbon tax, or cheaper natural gas.

Despite the pressing importance of using models to address domestic policy questions, no important problem is without international implications. To understand how changes in one country affect other economies, linking of models is extremely valuable. We have found the bilateral linking helpful in understanding the transmission of economic shocks as well as providing a valuable database for understanding the means of that transmission.

Ongoing research agenda of the partners includes:

Labor productivity and multi-factor productivity – The input-output database is a good framework for constructing KLEMS data. This tool has been used to project KLEMS

[16] See Bardazzi and Ghezzi (2014).

[17] Meade and Nyhus (2011).

components and productivity measures into the future. We continue to investigate alternative cost function and production function approaches to estimating productivity.

Model properties and dynamics – This includes a wide variety of topics, including the topic of dynamic multipliers discussed briefly above. A continuous task in model development is testing and evaluating the responses of models to shocks, both in the short- and long-term. Of special interest is the determination of the long-run growth path of the economy in an inter-sectoral model, and incorporating equations that allow for disequilibrium but encourage returning to the growth path.

Energy-environment modeling – Several of the models have been extended to incorporate more detailed information on energy systems and emissions. Separate models have also been developed that link to the main national model. The modeling framework is also quite suited to the study of water resource issues.

Health care and demographics – The projected rise in health care costs in some countries, particularly the U.S. will cause large structural shifts and have implications for productivity and GDP growth. Personal consumption equations that include demographics are a good tool for understanding the growth in this health care cost, and the integrated model can be used to investigate the implications for the consumption and production of other non-health goods and services.

Infrastructure investment - Roads, bridges, electric and water facilities, airports and other infrastructure are known to be important to the overall productivity and competitiveness of a country. Analyzing these productivity effects econometrically poses many problems, but information from transportation and engineering studies can help. The model can be used to estimate the cost of substandard infrastructure to the economy.

International trade and investment – Bilateral and multilateral country studies have analyzed several free trade agreements, and expansion of the EU. Several partners have also explored the offshoring of jobs, or “hollowing out” due to foreign direct investment and transfer of operations overseas.

Labor force and education – Incorporation of an employment matrix (occupation by industry) enables the projection of demand for workers of various skill and education levels. These projections can be combined with projections of labor force by education and skill level to detect shortages or bottlenecks (as well as oversupply) of certain labor categories.

The Inforum partners will hold the next international conference in Alexandria, Virginia, in the first week of September 2014. The papers will include reports on studies done by Inforum members, reports on modeling improvements and model development, theoretical issues in empirical input-output modeling, as well as a report on the progress of the update of the Inforum Bilateral Trade Model.

The Inforum team will continue to build new versions of the national models, and develop models for new countries. Furthermore, there are ongoing efforts in several countries to apply Inforum modeling software and techniques to the development of regional models and special purpose energy-environment models. The U.S. group and the partners continue to learn from each other, especially at the annual conferences. We are striving to adopt new techniques from both the macro and the IO literature into the design of our models and software. We are especially eager to work with researchers in countries which do not currently have an Inforum model, such as Portugal. Please contact us if you are interested!

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